Ceylon Graphene Technologies

LOLC ADVANCED TECHNOLOGIES

SLINTEC
SRI LANKA INSTITUTE OF NANOTECHNOLOGY (PVT) LTD.

ABOUT GRAPHITE AND GRAPHENE

Sri Lankan Vein Graphite

Sri Lanka is the only country in the world that produces vein graphite and it is one of the country's main mineral products. Sri Lanka has been mining graphite, better known locally as 'Miniran' for over two centuries. Sri Lanka is the only country to mine ultra-pure highly crystalline vein graphite with more than 98% of carbon purity in the world over the last 100+ years. Currently producing a negligible 300 tons of Graphite monthly, Sri Lankan graphite is mainly sourced from three mines which include Bogala, Kahatagaha and Ragedara. Sri Lankan graphite is world renowned for its superior quality and uniqueness. One of the many advantages of mining Graphite in Sri Lanka is its low environmental impact.

Introduction to Graphene

Graphene's unique combination of extraordinary properties offers a fascinating material platform for the development of next-generation technologies in many areas – superfast high capacity batteries, ultrasensitive sensors, anti-corrosion coatings, water treatment, medicine and technologies.

Graphene is a sheet of carbon atoms in a honeycomb structure. Graphene is a 2D material with a one atom thick layer. Many stacked graphene sheets create graphite.

Structure of Graphene

Graphene can be a parent form for many carbon structures, like the above-mentioned graphite, carbon nanotubes (which can be viewed as rolled-up sheets of graphene formed into tubes) and buckyballs (spherical structures with a cage-like structure made from graphene only with some hexagonal rings replaced by pentagonal rings).

Graphene is one of the first and most famous examples of a 2D crystal. Two-dimensional materials and systems are fundamentally different from three-dimensional ones in many ways.

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MAIN PROPERTIES OF GRAPHENE

Atomic Thickness

A single layer is only one atom tick (therefore called 2D or two-dimensional) about 0.335 nanometers

Impermeability

Even the smallest atom (helium atom) cannot pass through a sheet of graphene

Electron Mobility

The highest electron mobility of all electronic materials with theoretical limit of 200,000 cm2/Vs (>100x higher than silicon)

Thermal Conductivity

1500-2500 W/m K at room temperature, higher than diamonds

Strength

Defect-free, monolayer graphene is the strongest material ever tested with a strength of 42 N/m, which equates to an intrinsic strength of 130 GPa (>100x stronger than the strongest steel)

Electrical Resistivity

1x10-8 Ω m among the lowest of any known material at room temperature (35% less than copper)

Toughness and Stretch-ability

Defect-free, monolayer graphene is the strongest material ever tested with a strength of 42 N/m, which equates to an intrinsic strength of 130 GPa (>100x stronger than the strongest steel)

Stiffness

Experiments on defect-free graphene monolayer have yielded a Young's modulus of 1.0 TPa - one of the highest value of any material; about the same as diamond

LOLC ADVANCED TECHNOLOGIES

LOLC ADVANCED TECHNOLOGIES

A wholly - owned subsidiary of LOLC Holdings PLC, LOLC Advanced Technologies (Pvt) Ltd Provides advanced technological consultation support to companies under the LOLC umbrella in the fields of precision agriculture, process improvements for cinnamon agronomy and value addition, new product development in plant nutrition and agro – Chemistry.

LOLC Advanced Technologies (Pvt) Ltd, was set up to explore sustainable business opportunities in the market with augmentation of Science and Technology.

LOLC GEO TECHNOLOGIES

LOLC GEO Technlogies (LOGT) processes 3 graphite exploration licences covering 46 square kilometres in Dodangaslanda, Godakawela, Rakwana and Paragoda areas of Kurunegala, Matale, Kandy and Rathnapura Districts of the country and a mining license for Dodangaslanda area in which the mining activities are carried out.

The carbon content of graphite samples extracted from Dodangaslanda mine exceeds 95% reflecting countries' renowned name for high quality graphite.

VALUE CHAIN CAPABILITIES OF CGT

Mining of Raw Materials

Graphene Production

QC Testing

Final Product

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ABOUT CEYLON GRAPHENE TECHNOLOGIES

Ceylon Graphene Technologies (CGT), a joint venture between the LOLC Advanced Technologies and the Sri Lanka Institute of Nanotechnology (SLINTEC), is Sri Lanka's first graphene and advanced material company and a national laboratory. CGT is the most competitive graphene manufacturer, product developer and researcher in the world due to the complete product life cycle.

CGT Production Plant Environment

Located in the suburbs of Colombo at the Nanotechnology and Science Park in Homagama, the CGT Production Plant is situated amongst coconut fields and various types of local trees. At CGT, we recognize that being a sustainable company is key to our communities, our ecology and our operations but we also realize it poses a chance to do what is right and to make a real difference in how we operate as a business.

We have progressively looked at making a net positive impact through our operations. One of the key positive impacts is that solar panels are fitted on our production plant roof, 30%-40% of the electricity used for the CGT Production Plant is produced using solar power. CGT hopes to keep finding more ways to maintain a sustainable work environment in the years to come.

CGT'S COMPETITIVE ADVANTAGES

With our dedicated in-house research laboratories, CGT has a huge advantage compared to many other graphene companies. CGT's graphene production, R&D works, and quality assurance testing are all done within a 2km radius of each other, using state-of-the-art testing machines. Due to these advantages, we can start production and finish quality assurance testing for orders within a short lead-time.

In the coming years, graphene of high purity will be essential for many industries around the world. The final properties of the obtained graphene depend mainly on the starting raw material, which CGT has a major advantage over because of the ultra-pure, high-quality Vein Graphite.

CHARACTERIZATION OF CGT GO & RGO TEST ANALYSIS SUMMARY

Bulk Density Analysis

CGT RGO showed an average bulk density of 0.00721 ± 0.00026 g/mL (The best seen in literature)

Particle Size Distribution Analysis

Both GO & RGO showed larger particle size distribution compared to other commercially available Graphene products, which implies its suitability for many applications.

SEM Analysis

CGT RGO reports high lateral size (approx. length of 20.66 µm and approx. width of 13.49 µm) To have large particle size is advantageous for many applications mainly Graphene composites.

BET Analysis

CGT RGO on average report 650+ m2/g BET Surface Area, which implies its high quality for energy storage application solutions.

TEM Analysis

CGT RGO indicated existence of an excellent graphitic crystalline structure confirming its high quality.

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CURRENT CGT PRODUCT LINE

Graphene Oxide Powder

Graphene oxide (GO) is the oxidized form of graphene. It is a single-atomic layered material that is formed by the oxidation of graphite which is cheap and readily available. GO is a unique material with various oxygen containing functionalities such as epoxide, carbonyl, carboxyl, and hydroxyl groups.

APPLICATION AREA

- Research & Development
- Construction Material
- Paint and Coatings
- Water Filtration
- Plastic & Polymer Composites
- Oil & Lubrication

Reduced Graphene Oxide Powder

Reduced Graphene Oxide (rGO) is produced by reducing Graphene Oxide (GO) using chemical, thermal, or electrochemical methods. rGO is one of the most obvious solution to be used for industrial applications such as energy storage.

APPLICATION AREA

- Research & Development
- Battery Additive
- Energy Storage
- Plastic & Polymer Composites
- Oil & Lubrication

Expanded Graphite Powder

Expanded Graphite (EG) is produced from natural graphite flakes with well-ordered high-crystalline structure. Graphite flakes are mixed with a highly oxidizing acid to form an intercalation compound which is expanded by applying high temperatures.

APPLICATION AREA

- Oil & Lubrication
- Paint and Coatings
- Automotive
- Energy Storage
- Construction Material

Electro-Exfoliated Graphite Powder

Electro-Exfoliated Graphite is a promising product that is produced by using different electrolytes (e.g., acids, salts, and ionic liquids) and an electrochemical cell. Electrochemical exfoliation has attracted attention due to its easy, fast, and environmentally benign nature to produce high quality graphene.

APPLICATION AREA

- Oil & Lubrication
- Automotive
- Composites
- Energy Storage
- Construction Material

Graphene Oxide Water Dispersion/Paste

Graphene oxide (GO) is the oxidized form of graphene. It is a single-atomic layered material that is formed by the oxidation of graphite which is cheap and readily available. Graphene oxide is easy to process since it is dispersible in water and other solvents. At CGT, we cater to dispersions in different concentrations, as well as pastes.

APPLICATION AREA

- Research & Development
- Construction Material
- Paint and Coatings
- Composites
- Water Filtration
- Plastic & Polymer Composites
- Oil & Lubrication

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GRAPHENE OXIDE

Graphene has a two-dimensional structure of a carbonaceous new material. Graphene has excellent electrical, thermal and mechanical properties. Graphene oxide (GO) is a unique material with various oxygen containing functionalities such as epoxide, carbonyl, carboxyl and hydroxyl groups.

APPLICATION AREA

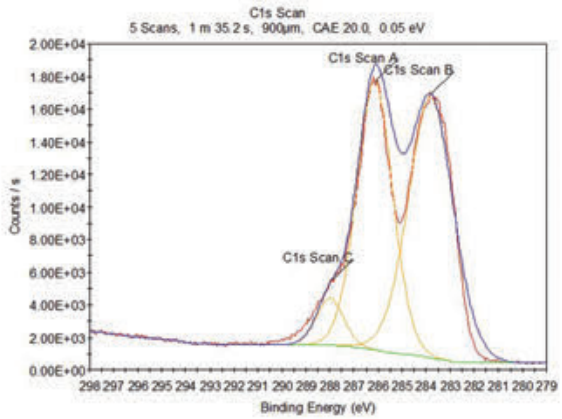
- RESEARCH & DEVELOPMENT
- CONSTRUCTION MATERIAL
- WATER FILTRATION
- PLASTIC & POLYMER COMPOSITES
- OIL & LUBRICATION
- ADVANCED APPLICATIONS

Start-up Graphite	Sri Lankan C99+ Vein Graphite, Particle Size range 63-90 µm
Appearance	Brown color dry powder
Tapped Density	~ 0.53 g/cm3
Dispersibility	Polar solvents (water, ethanol, DMF, etc.)

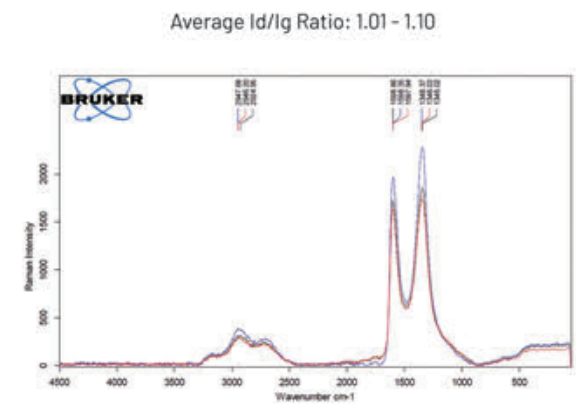
C/O ratio: 1.9 - 2.5 — **X-ray Photoelectron Spectroscopy (XPS)**

Name	O1s	C1s	S2p	Si2p
Avg %	28.64 - 34.04	61.56 - 68.98	0.73 - 1.79	0 - 0.77

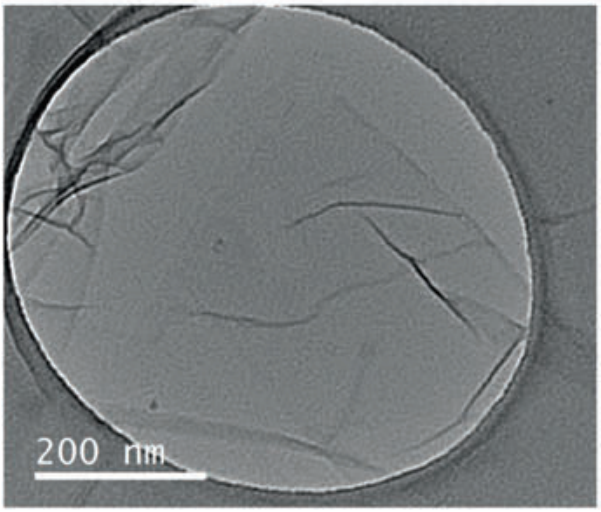
CARBON 1S XPS NARROW SCAN

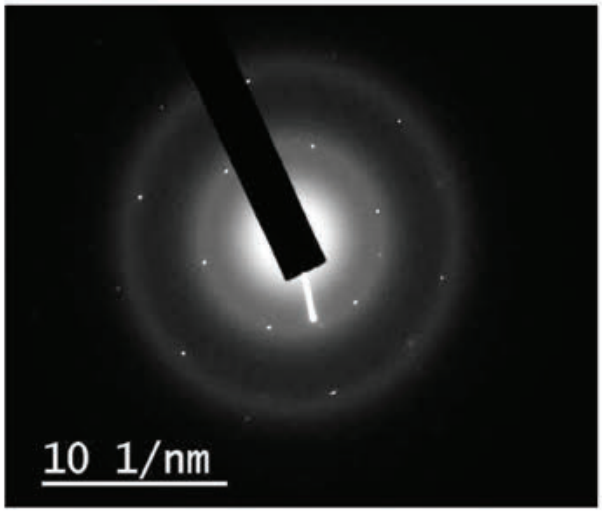


RAMAN ANALYSIS

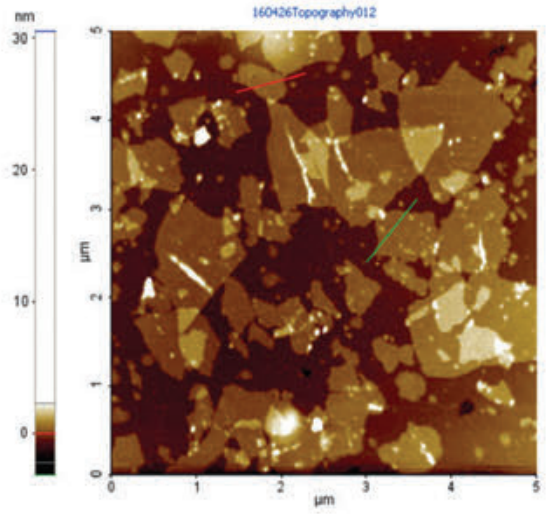


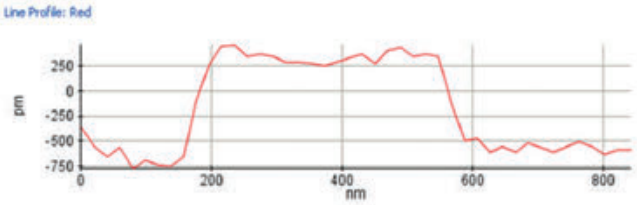
TRANSMISSION ELECTRON MICROSCOPE (TEM)

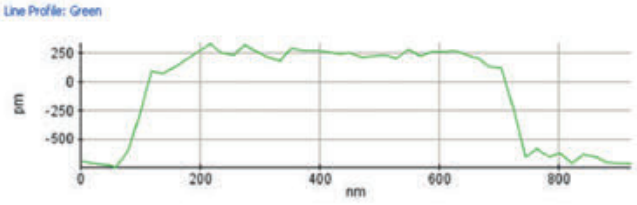




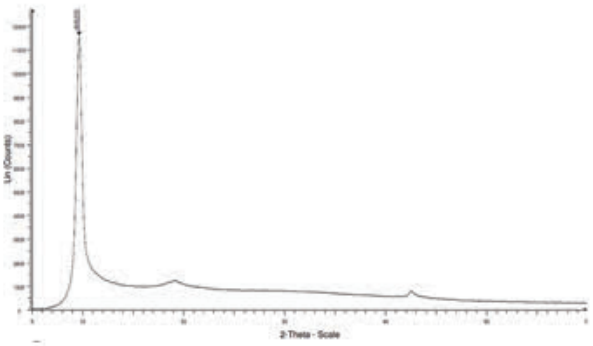
AFM IMAGES



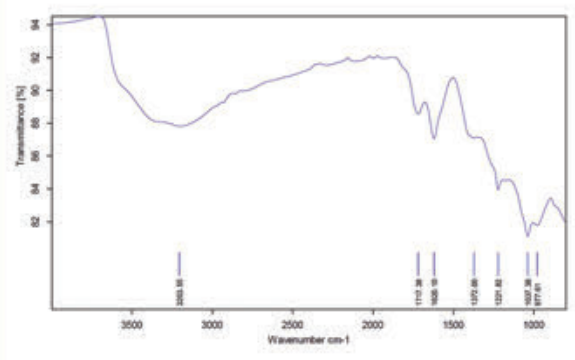




X-RAY POWDER DIFFRACTION (XRD)



FTIR ANALYSIS



Ceylon Graphene Technologies

REDUCED GRAPHENE OXIDE

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APPLICATION AREA

- RESEARCH & DEVELOPMENT
- BATTERY ADDITIVE
- ENERGY STORAGE
- PLASTIC & POLYMER COMPOSITES
- OIL & LUBRICATION
- ADVANCED APPLICATIONS

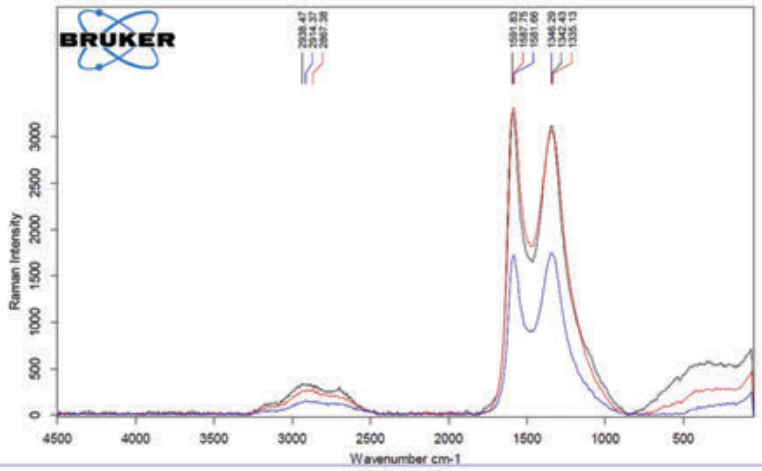
Start-up Graphite	Sri Lankan C99+ Vein Graphite, Particle Size range 63-90 µm
Appearance	Soft Black Powder Platelets
Tapped Density	5.9 x 10-3 g/cm3
BET Surface Area	500 – 700 m 2 /g

C/O ratio: 6.00 - 17.81 — **X-ray Photoelectron Spectroscopy (XPS)**

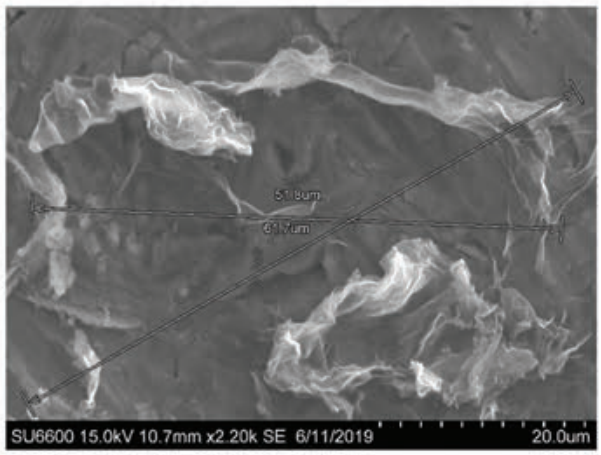
Name	C1s	O1s	S2p	Si2p
Avg %	85.48 – 93.64	5.26 – 14.10	0.00 – 1.10	0.00 – 0.40

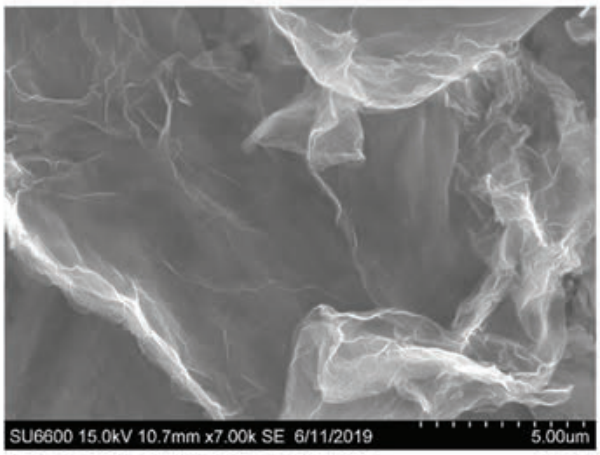
RAMAN ANALYSIS

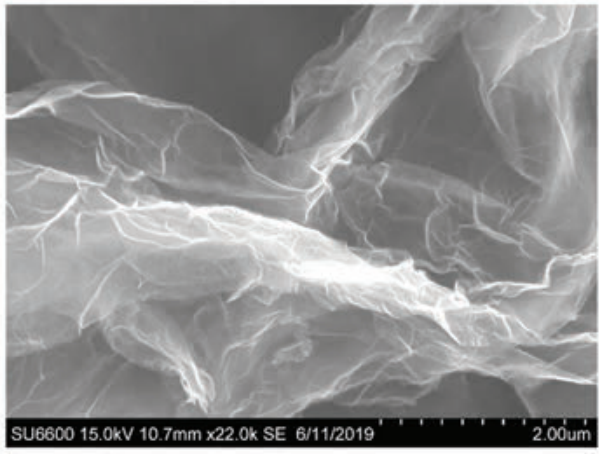
Average Id/Ig Ratio: 0.97 - 0.99

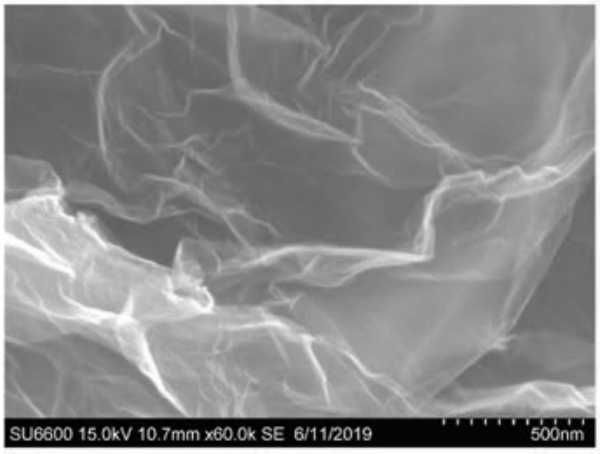


SCANNING ELECTRON MICROSCOPE (SEM)

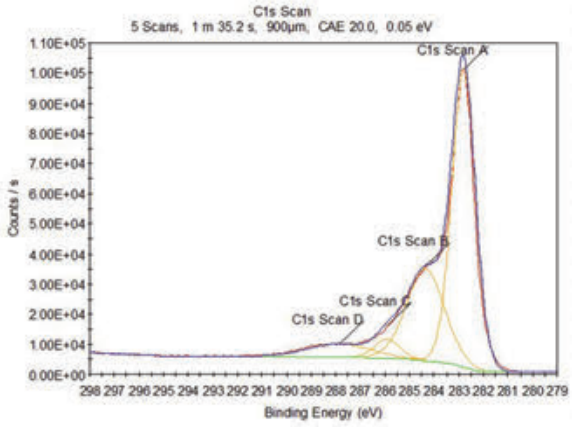








XPS NARROW SCAN C1S



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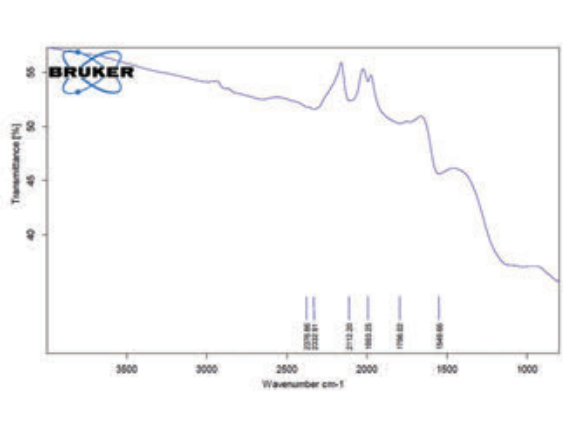


Ceylon Graphene Technologies

EXPANDED GRAPHITE POWDER

Expanded Graphite (EG) is produced from natural graphite flakes with well-ordered high-crystalline structure. Graphite flakes are mixed with a highly oxidizing acid to form an intercalation compound which is expanded by applying high temperatures.

APPLICATION AREA

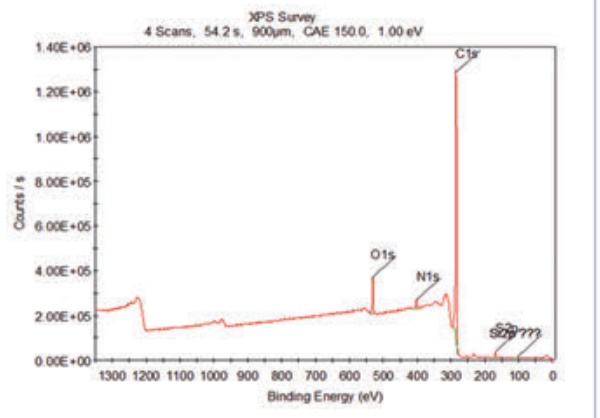
- OIL & LUBRICATION
- PAINT AND COATINGS
- AUTOMOTIVE
- ENERGY STORAGE
- CONSTRUCTION MATERIAL

Start-up Graphite	Sri Lankan C99+ Vein Graphite, Particle Size range 63-90 µm
Appearance	Soft black powder platelets
Tapped Density	~ 0.035 g/cm3

C/O ratio: 5.9-17.53 — **X-ray Photoelectron Spectroscopy (XPS)**

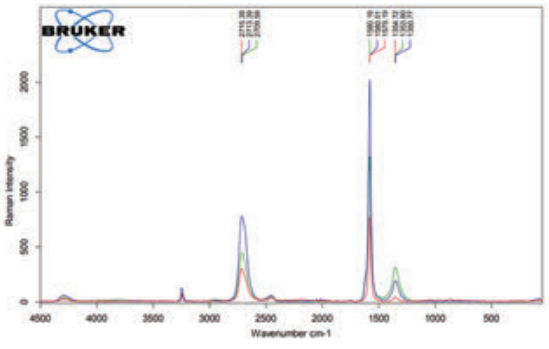
Name	C1s	O1s	S2p	Si2p
Avg %	83.48 - 91.68	5.23 - 14.13	0.00 - 1.06	0.00 - 2.03

CARBON 1S XPS NARROW SCAN



RAMAN ANALYSIS

Average Id/Ig Ratio: 0.05 - 0.09



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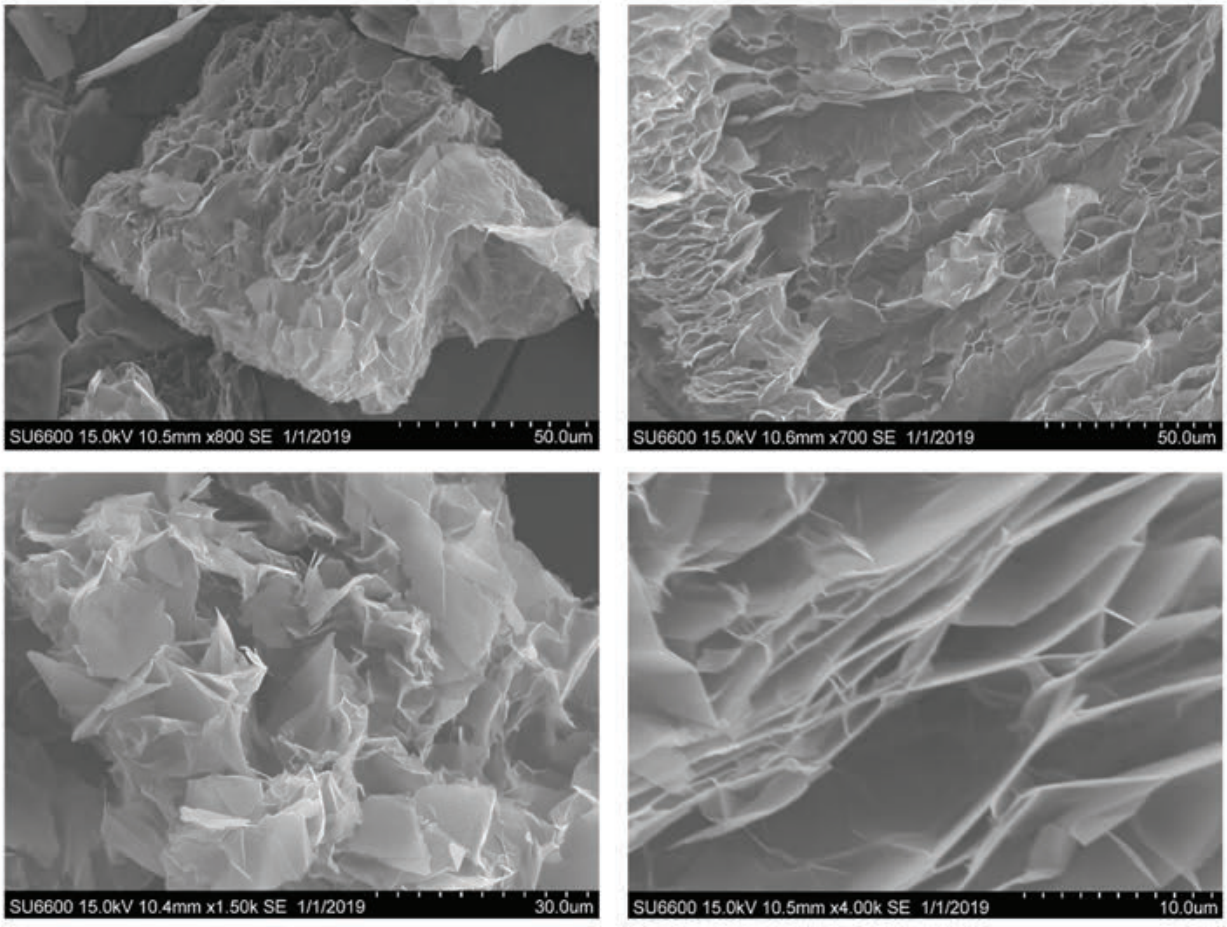

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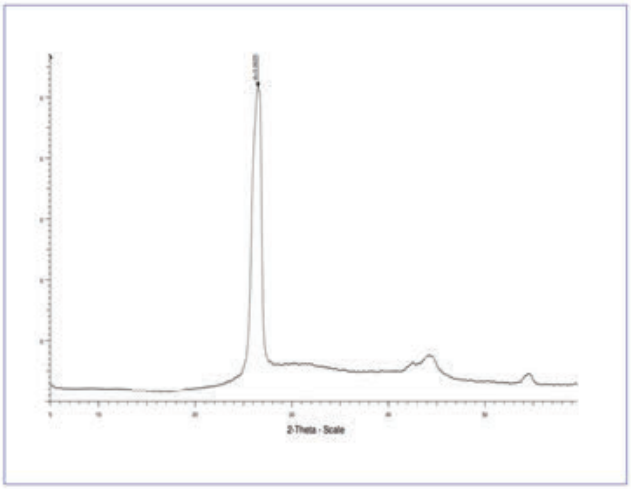

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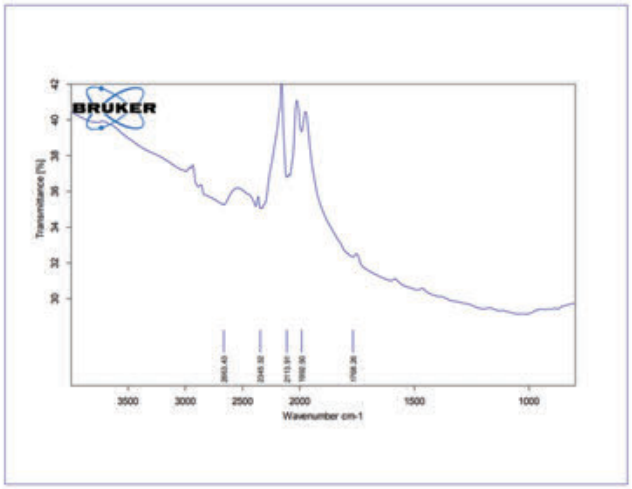


Ceylon Graphene Technologies

GRAPHENE OXIDE WATER DISPERSION/PASTE

Graphene oxide (GO) is the oxidized form of graphene. It is a single-atomic layered material that is formed by the oxidation of graphite which is cheap and readily available. Graphene oxide is easy to process since it is dispersible in water and other solvents. At CGT, we cater to dispersions in different concentrations, as well as pastes.

APPLICATION AREA

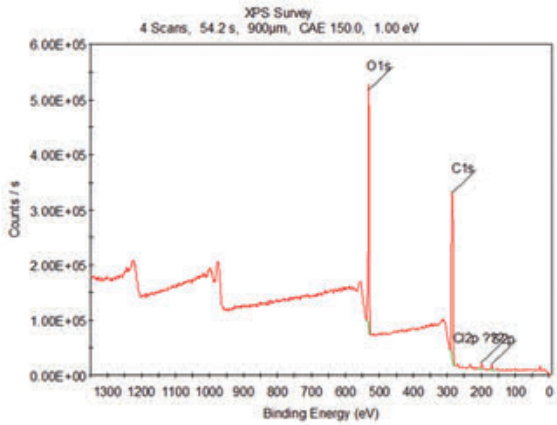
- RESEARCH & DEVELOPMENT
- CONSTRUCTION MATERIAL
- PAINT AND COATINGS
- COMPOSITES
- WATER FILTRATION
- PLASTIC & POLYMER COMPOSITES
- OIL & LUBRICATION

Start-up Graphite	Sri Lankan C99+ Vein Graphite, Particle Size range 63-90 µm
Appearance	Brown Dispersion/Paste
pH range	3-4

C/O ratio: 1.80 – 2.40 — **X-ray Photoelectron Spectroscopy (XPS)**

Name	C1s	O1s	S2p	Si2p
Avg %	61.81 - 69.27	28.81- 34.31	0.00 - 1.08	0.00 - 0.84

CARBON 1S XPS NARROW SCAN



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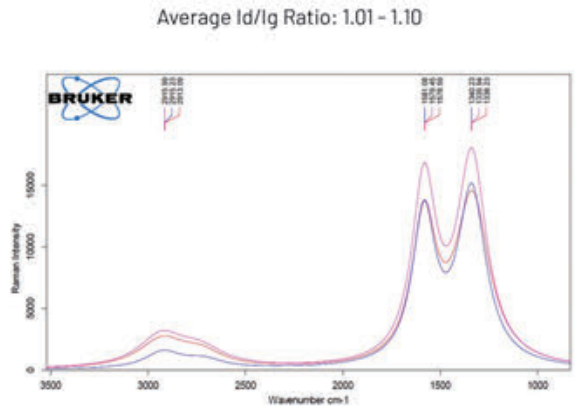

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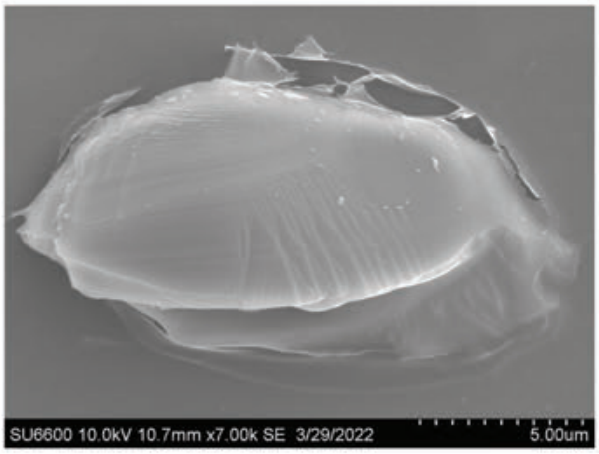
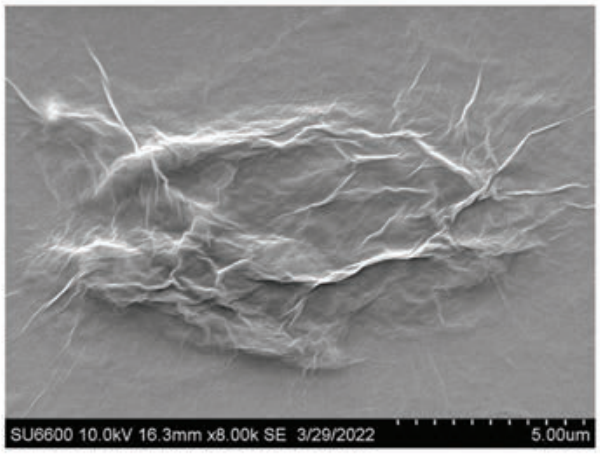
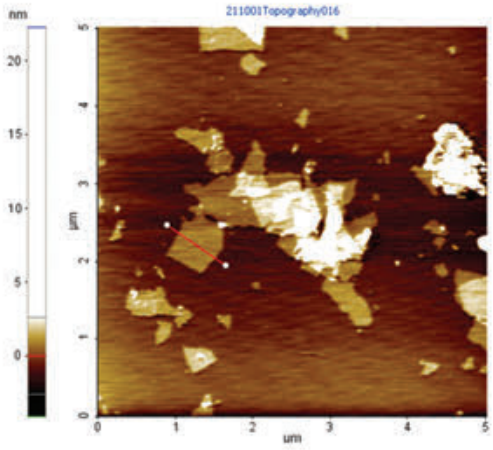
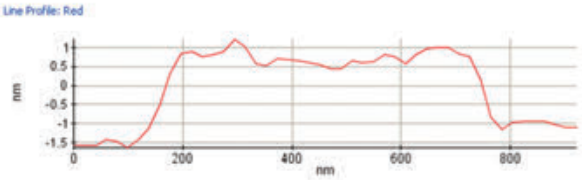
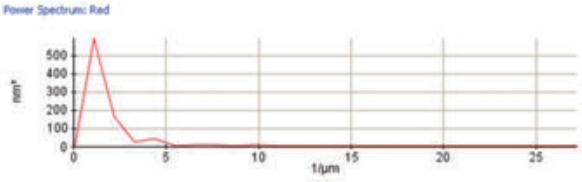




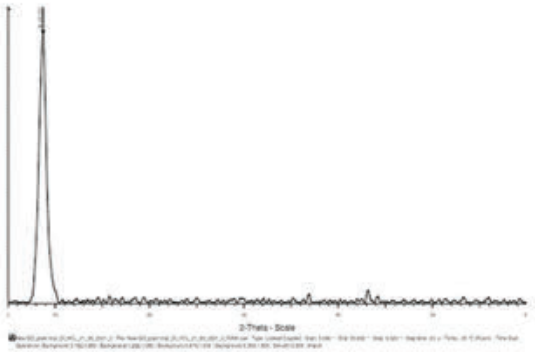
AFM IMAGES



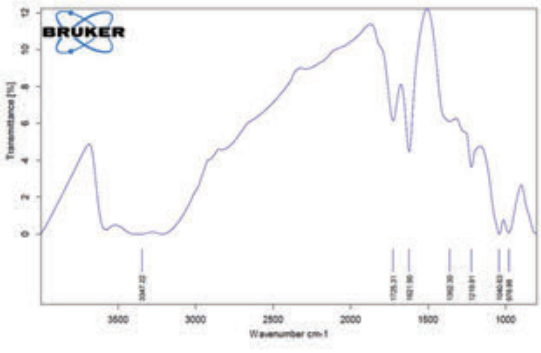




X-RAY POWDER DIFFRACTION (XRD)



FTIR ANALYSIS



Ceylon Graphene Technologies

CGT RESEARCH PROJECTS & VALUE-ADDED PRODUCTS

Current Progress of Graphene Battery Project

One of CGT's success stories is the project with Associate Battery Manufacturers to launch the first ever Graphene applied Lead Acid Battery. CGT has a state-of-the-art facility to conduct battery tests and develop additives for lead acid batteries.

From June 2020 to date, CGT has produced nearly 1400 batteries in the range of 35Ah. Currently we are focusing on production higher range batteries such as 65Ah, 70Ah, 90Ah and 105Ah batteries with graphene addition.

Produced batteries show cased significant improvement in performance such as:

15-25% Improvement in capacity

30-35% Improvement in charge

50% Reduction in water-loss, which will improve the life and performance

Graphene in Paint & Coatings

Graphene's high resistivity can make for durable coatings that do not crack and are resistant to water and oil, its excellent electrical and thermal conductive paints, and a strong barrier effect can contribute to extraordinary antioxidant, scratch-resistant and anti-UVA paints.

CGT has also started projects with ARC Research Hub for Advanced Manufacturing with 2D Materials in University of Adelaide, with one of the projects for fire retardant and protective coatings.

Graphene in Concrete Project

Number of trials have taken place in the UK and the University of Melbourne with CGT's Graphene Oxide to enhance both construction and road applications.

Addition of graphene derivatives can improve several features of cement composite as mentioned below:

- Improved compressive and flexural strength.
- The incorporation of graphene oxide in cement composites can block the transport of aggressive agents within cement matrix and improve the resistance to carbonation, frost and calcium leaching of cement composite.
- Graphene Oxide on cement composites includes the promotion of cement hydration, the refined pore structure, the compact microstructure, and the interfacial bonding with the matrix.
- Can bring certain smart properties and multi-functionality, such as EMI shielding, effectiveness, electrical conductivity, thermal conductivity, etc.

50% improvement in compressive strength

Graphene Polymer Composites Project

Research and development work for graphene polymer composites are ongoing, with huge potential thus far in thermal and electrical conductivity as well as mechanical properties. Sub-projects in this include:

- Conductive PU Coatings (evaluate the thermal and electrical conductivities of the nanocomposites).
- Conductive Rubber and Silicon Sheets (to produce latex or solid rubber).
- Nylon Nanocomposites (to produce nylon/graphene nanocomposite sheets or strands).

CURRENT INTERNATIONAL PROJECTS IN GRAPHENE APPLICATIONS

United Kingdom
Concrete Applications:

Graphene enhanced concrete applications for roads and construction with UK based companies such as EasyMix, Cemex, TAG Construction and Atkins. This ongoing project will also be tied to the UK Highways in the future.

Australia
Concrete Applications:

Concrete based projects in the areas of roads and construction in Australian universities such as University of Melbourne and University of Canberra have shown extraordinary results. Extensive trials have been conducted to view the compressive, tensile and abrasion resistance of graphene enhanced concrete.

United Kingdom
Paints & Coating Applications:

UK based company called Eico Paints is currently working with CGT to conduct trials for paint & coating applications. Specifically for their applications for fireproof and waterproof paints.

Australia
Composite & Water Filtration Applications:

Main project areas with University of Adelaide are with Graphene enhanced Water Filtration and Paint & Coatings (for fire and water proofing).

South Korea & India
Battery Applications:

Graphene enhanced battery applications for lead-acid, lithium ion and air-aluminum batteries with South Korean based company Standard Graphene and Indian based company All India Metals is currently underway.

South Korea & India
Concrete and Composite Applications:

Graphene enhanced concrete applications for building construction in South Korea and India, preliminary testing is ongoing. Graphene enhanced lubricants and polymer composites works are also in the initial stages.

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QUALITY CONTROL CAPABILITIES AT CGT

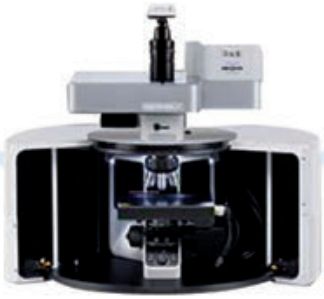
Fourier Transform Infrared Spectroscopy (FTIR)

Fourier Transform Infrared Spectroscopy (FTIR) identifies chemical bonds in a molecule by producing an infrared absorption spectrum. The spectra produce a profile of the sample, a distinctive molecular fingerprint that can be used to screen and scan samples for many different components.

Ultraviolet-visible Spectroscopy (UV-VIS)

UV-Vis Spectroscopy is used for the quantitative determination of different analysts at one given time or over a desired period of time. This refers to absorption spectroscopy or reflectance spectroscopy in part of the ultraviolet and the full, adjacent visible regions of the electromagnetic spectrum.

Raman Spectroscopy (RAMAN)



Raman is a spectroscopic technique typically used to determine vibrational modes of molecules, although rotational and other low-frequency modes of systems may also be observed. Raman spectroscopy is commonly used in chemistry to provide a structural fingerprint by which molecules can be identified.

X-Ray Diffraction Spectroscopy (XRD)

X-ray diffraction analysis (XRD) is a technique used in materials science to determine the crystallographic structure of a material. XRD works by irradiating a material with incident X-rays and then measuring the intensities and scattering angles of the X-rays that leave the material.

Brunauer-Emmett-Teller (BET)

Brunauer-Emmett-Teller (BET) theory aims to explain the physical adsorption of gas molecules on a solid surface and serves as the basis for an important analysis technique for the measurement of the specific surface area of materials.

X-Ray Photoelectron Spectroscopy (XPS)

X-ray photoelectron spectroscopy (XPS), also known as electron spectroscopy for chemical analysis (ESCA), is a technique for analysing a material's surface chemistry. XPS can measure elemental composition as well as the chemical and electronic state of the atoms within a material.

Transmission Electron Microscopy (TEM)

Transmission electron microscopy (TEM) is a microscopy technique in which a beam of electrons is transmitted through a specimen to form an image. TEM is capable of imaging at a significantly higher resolution than light microscopes, owing to the smaller de Broglie wavelength of electrons.

Scanning Electron Microscopy (SEM)

A scanning electron microscope (SEM) projects and scans a focused stream of electrons over a surface to create an image. The electrons in the beam interact with the sample, thereby producing various signals that can be used to obtain information about the surface's topography and composition.

Thermogravimetric Analysis (TGA)

Thermogravimetric analysis (TGA) is a powerful technique for the measurement of thermal stability of materials including polymers. In this method, changes in the weight of a specimen are measured while its temperature is increased. Moisture and volatile contents of a sample can be measured by TGA.

Atomic Force Microscopy (AFM)

Atomic Force Microscope (AFM) is a type of a Scanning Probe Microscope which is a powerful tool that allows imaging at a near atomic resolution for the analysis of surface topography in 2D as well as in 3D. This instrument could be used to study the surface roughness, feature sizes such as step height and the other dimensions involved.

Particle Size Analyser (PSA)

Particle size analysis is used to characterise the size distribution of particles in a given sample. Particle size analysis can be applied to solid materials, suspensions, emulsions and even aerosols. There are many different methods employed to measure particle size.

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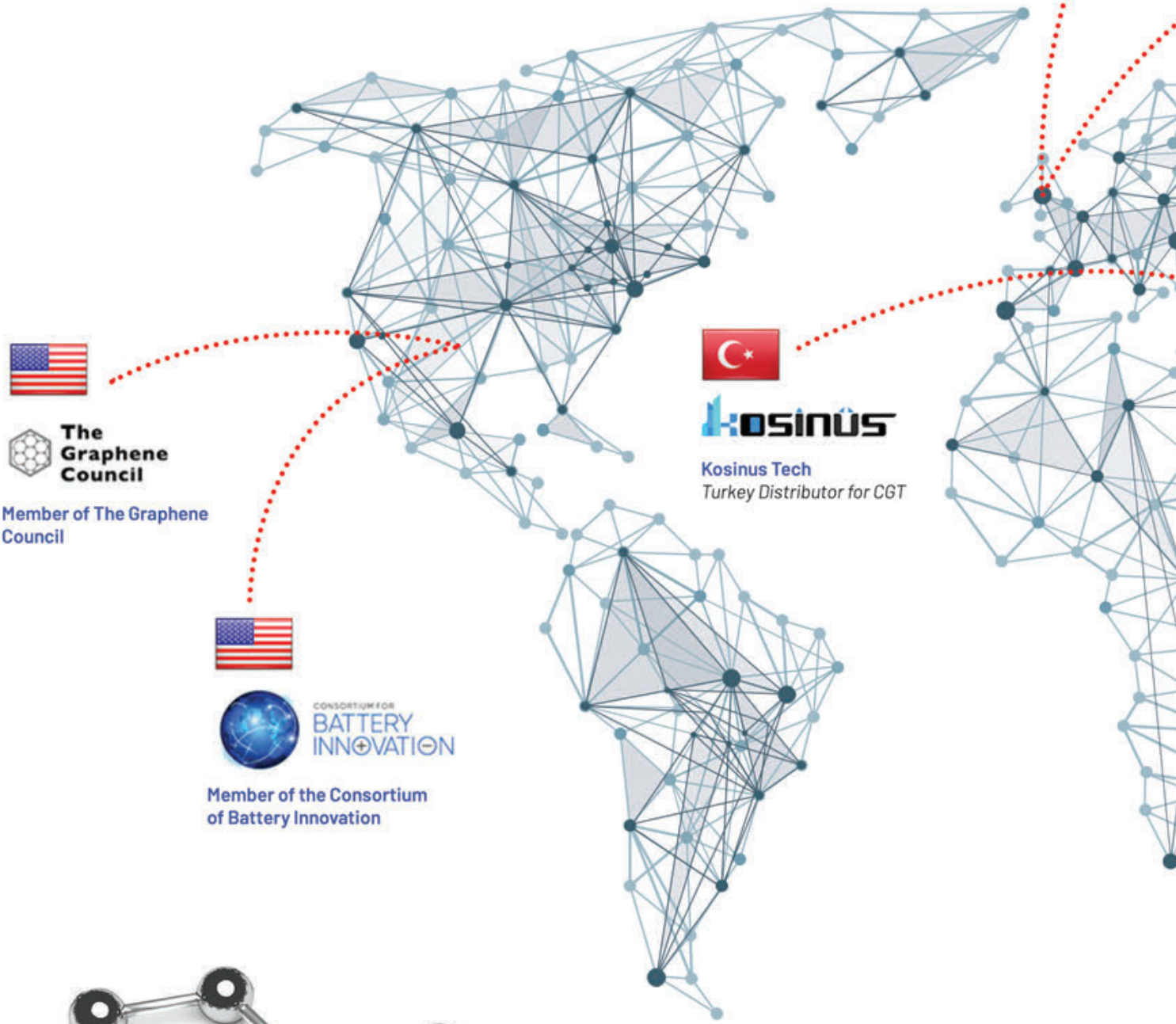
CURRENT INTERNATIONAL PARTNERSHIPS & MEMBERSHIPS



The Graphene Council

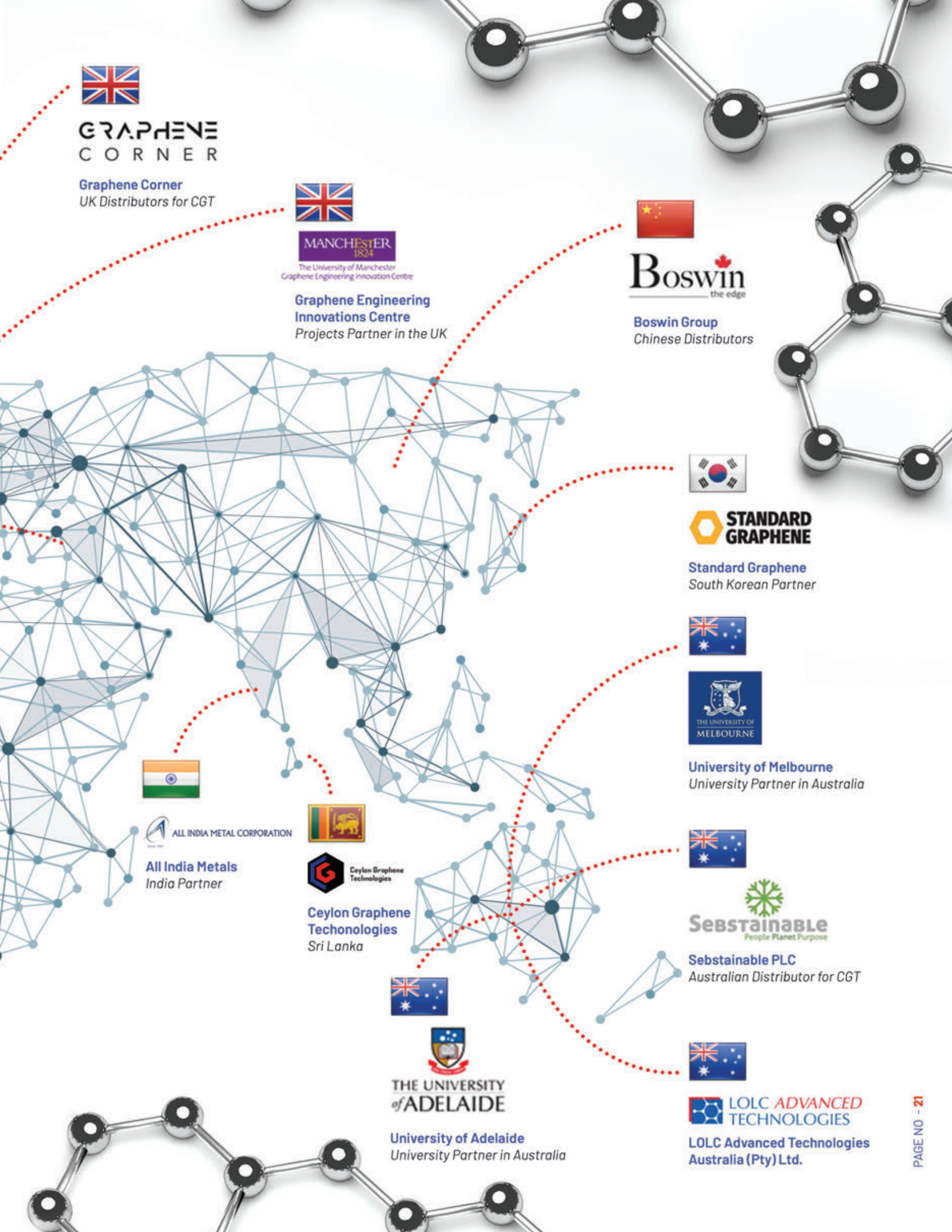
Member of The Graphene Council

Kosinus Tech

Turkey Distributor for CGT

CONSORTIUM FOR BATTERY INNOVATION

Member of the Consortium of Battery Innovation


GRAPHENE
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Graphene Engineering Innovation Centre
Graphene Engineering
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TECHNOLOGIES
LOLC Advanced Technologies
Australia (Pty) Ltd.

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University of Adelaide

Prof Priyan Mendis

Lead Partner in Concrete and Cement Applications
University of Melbourne

Debbie Nelson

Lead Partner in Digital Communications and Social Media
Nixene Publishing

LOLC HOLDINGS PLC

Admired as Sri Lanka's most profitable corporate entity; the largest Non - Banking Financial institution (NBFI) and one of the most strategically diversified conglomerates, the LOLC Group is engaged in leisure, plantations, agriculture, renewable energy, construction and real estate, manufacturing and trading, technology, research and innovation and other strategic investments. As a leading player in Sri Lanka's MSME sector, the LOLC Group has been a catalyst in facilitating financial inclusion, whilst striving to maximise environmental benefits through green operations and processes in line with its triple bottom line focus.

FINANCIAL SERVICES

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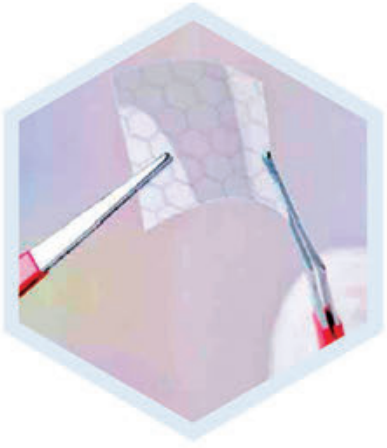
CONSTRUCTION & REAL ESTATE

LEISURE



TECHNOLOGY, RESEARCH & INNOVATION

RENEWABLE ENERGY

LOLC
imagine the possibilities

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- LOLC DEVELOPMENT FINANCE
- LOLC VENTURA (INDONESIA)
- LOLC FINANCE PHILIPPINES INC
- LOLC FINANCE ZAMBIA
- MYANMAR MICRO FINANCE
- LOLC FINANCE DR Congo
- الأولى FINANCE EGYPT
- LOLC KENYA Microfinance Bank
- LOLC BANK PHILIPPINES Inc. A Thrift Bank
- LOLC Microfinance Bank (Pakistan)
- អិលអូអិលស៊ី (ខេមបូឌា) អិមអិលស៊ី LOLC (Cambodia) Plc.
- Fina Trust Microfinance Bank (NIGERIA)
- ExpressCredit.co.mw (MALAWI)
- (TANZANIA)
- KARAT (TAJIKISTAN)
- Fazo S (TAJIKISTAN)
- LOLC SECURITIES
- LOLC Factors
- LOLC LIFE ASSURANCE
- LOLC GENERAL INSURANCE
- AL-FALAAH ALTERNATE FINANCIAL SERVICES
- iPay
- Serendib Insurance (Cambodia)
- LOLC Investments
- HNB
- SEYLAN BANK PLC The bank with a heart
- HDFC BANK The Housing Bank...
- SDB bank Leads the Nation
- LOLC MOTORS
- LOLC Technologies
- LOLC ADVANCED TECHNOLOGIES
  - LOLC GEO TECHNOLOGIES
  - FORTI GRAINS
  - Ceylon Graphene Technologies
- URUMAYA RESOURCES (ZIMBABWE)

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Browns Machinery (Cambodia) Co. Ltd.

Browns
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UDAPUSSELLAWA PLANTATIONS
MATURATA PLANTATIONS
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AgStar
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SIERRA LEONE
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THE CALM RESORT & SPA
DICKWELLA RESORT & SPA
Riverina Resorts
THE ELEPHANT CORRIDOR
AVANI Hotels & Resorts
Club Hotel Dolphin
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LOLC ADVANCED TECHNOLOGIES

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